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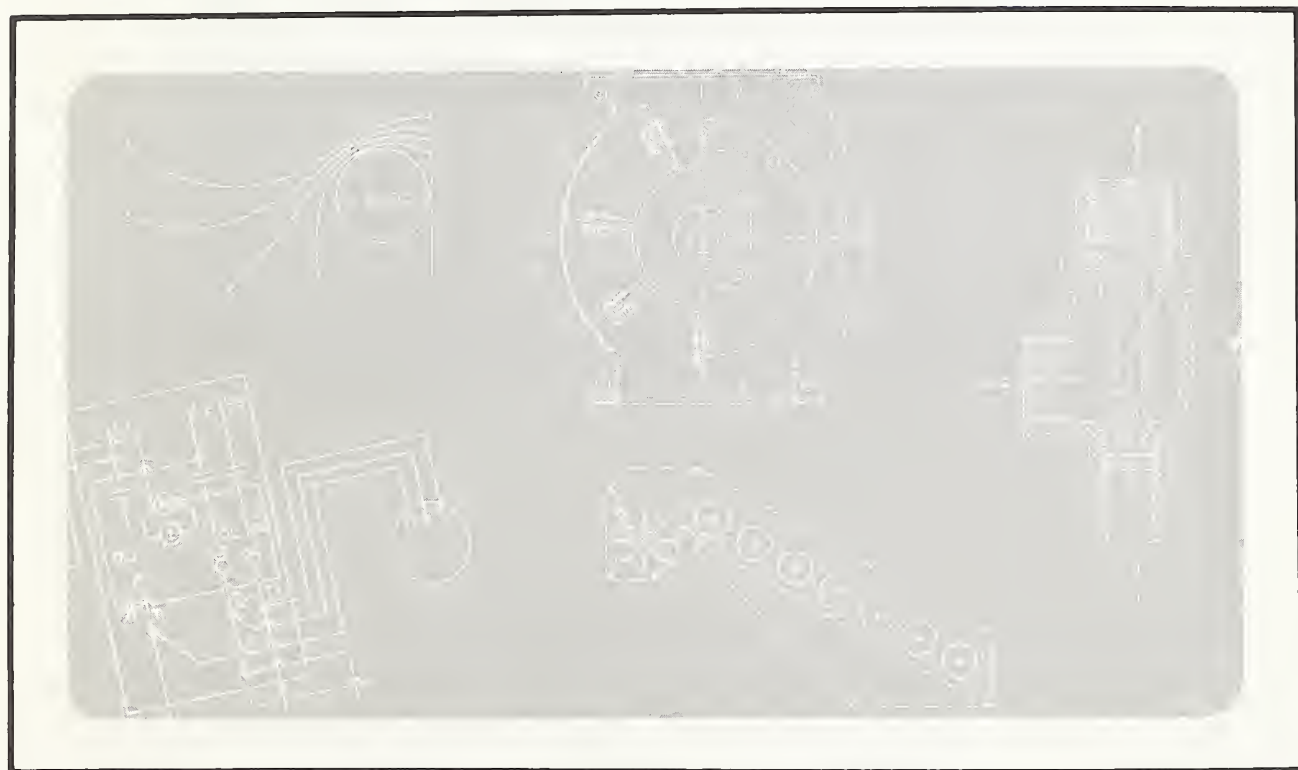
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In-Transit Temperatures of Leatherleaf Fern and Celery Shipped in Commercial and Experimental Van Containers to Europe

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In-Transit Temperatures
of Leatherleaf Fern and Celery Shipped
in Commercial and Experimental Van Containers
to Europe .

By L. A. Risse,¹ W. G. Kindya,² T. Moffitt,³ W. R. Miller,⁴ and R. E. McDonald⁵

ABSTRACT

This report describes the results of two ocean shipments. The purpose of the first shipment was to monitor the product and air temperatures in a USDA-developed van container loaded with freshly cut leatherleaf fern in order to determine how close the average fern temperature would be to the thermostat setting on the refrigeration unit (37° F). The second shipment was made to determine if temperatures of celery would be maintained more uniformly and more closely to the thermostat setting in the USDA van container than to the setting in the commercial van container when both thermostats were set at 34° F. The loads of both shipments were inspected on arrival to determine if the loading patterns of the shipping boxes were intact and to check the condition of the fern and celery. Fern temperatures at loading in the experimental van, which has under-the-floor forced-air distribution that forces refrigerated air through a tightly stacked load, ranged from 47° to 55° F and after 48 hours in transit, from 38° to 40° F (average of 39° F). Temperatures remained within that range until 135 hours after loading and ranged from 37° to 39° F until 240 hours after loading. At destination, 375 hours after loading, temperatures ranged from 40° to 41° F. In the celery shipment, this van had loading temperatures ranging from 41° to 46° F and after 48 hours in transit, from 37° to 40° F. Celery temperatures at loading in the commercial van, which depends on perimeter cooling and air-stack patterns to pass refrigerated air around and

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through the load, ranged from 42° to 48° F and after 48 hours in transit, from 30° to 44° F. Thus, the range in temperatures of celery in the USDA van was narrower and closer to the thermostat setting after 48 hours in transit than that of the commercial van. The refrigeration units of both vans were inoperative from 48 to 160 hours after loading, at which point celery temperatures ranged from 40° to 51° F in the USDA van and from 39° to 50° F in the commercial van. At destination, 420 hours after loading, celery temperatures ranged from 35° to 37° F in the USDA van and from 33° to 38° F in the commercial van. At final destination, the loading patterns of both shipments were intact. There was no evidence of freeze damage to the fern or celery, but bacterial soft rot had infected 5 to 25 percent of the celery stalks in several boxes that were examined in both vans. Index terms: celery, containerization, leatherleaf fern, loading patterns, ocean transportation, refrigerated van containers, temperature control.

INTRODUCTION

Perishable agricultural products transported from producing areas to consuming areas in refrigerated trailers and van containers must be held at optimum temperatures to maintain product quality during shipment and insure adequate shelf life at destination. High relative humidity and proper air distribution are also important. Temperature control is especially critical when transporting fresh fruits and vegetables that require temperatures near their freezing point. Even small variations of temperature in this critical zone can result in freeze damage or chill injury to the product. Celery and freshly cut fern fall into this category. The optimum in-transit temperature for celery is 32° F and for fern is 34° to 40° F, and their freezing points are approximately 31.5° and 29° F (Lutz and Hardenburg 1968).

The refrigeration unit and van-container body must function as an integral unit to provide the proper environment for highly perishable products during transit. Poor air distribution and inadequate stacking patterns can often lead to large variations of temperature within a van container, resulting in damage to products from freezing or overheating. Refrigeration-unit and van-container designs have continually been modernized to meet the requirements of perishables in transit. Improvements are also needed in the air-delivery system to the cargo (Breakiron 1974). Air-stacking patterns that allow refrigerated air to move through rather than around the load have been developed to help overcome some temperature-maintenance problems. However, air-stack patterns reduce payloads and may increase loading and unloading

costs. These loading patterns may also result in damage to both shipping box and product when the shipping boxes are not stacked in register or columns.

The U.S. Department of Agriculture is testing the concept of an under-the-floor forced-air distribution system in cooperation with private industry in an effort to determine how well this system would function under commercial conditions and if it would eliminate some of the air-distribution and box-stacking problems (Breakiron 1977, Goddard 1974). The effectiveness of the system is derived in part by the large air-return area and the controlled-air plenum under the floor at the load-mass interface, which is always constant and permits equal air-pressure buildup along the entire bottom surface of the load mass. Expected benefits to be derived from the adoption of such a system include (1) more precise thermostatic control of the refrigerated air delivered to the cargo; (2) more uniform product temperatures throughout the load during transit; (3) tight stacking of shipping boxes to eliminate complicated stacking patterns, which would result in more efficient loading and allow larger payloads; and (4) more effective removal of latent and respirational heat from the load. Stationary tests and shipping tests have been conducted to determine the effectiveness of this system (Hinsch et al. 1978, McDonald et al. 1979, Stewart 1976). The results indicated that the system was effective.

This report describes the results of two additional ocean shipments from Florida to Europe. The purpose of the first shipment was to monitor the product and air temperatures in the USDA-developed van container loaded with leatherleaf fern in order to determine how close the average

temperature of the fern would be to the thermostat setting on the refrigeration unit. The second shipment was made to determine if the temperatures of celery would be maintained more uniformly and more closely to the thermostatic setting in the USDA van container than to the setting in a commercial van container. In addition, the loads of both shipments were inspected on arrival to determine if the loading patterns of the shipping boxes were intact and to check the condition of the products.

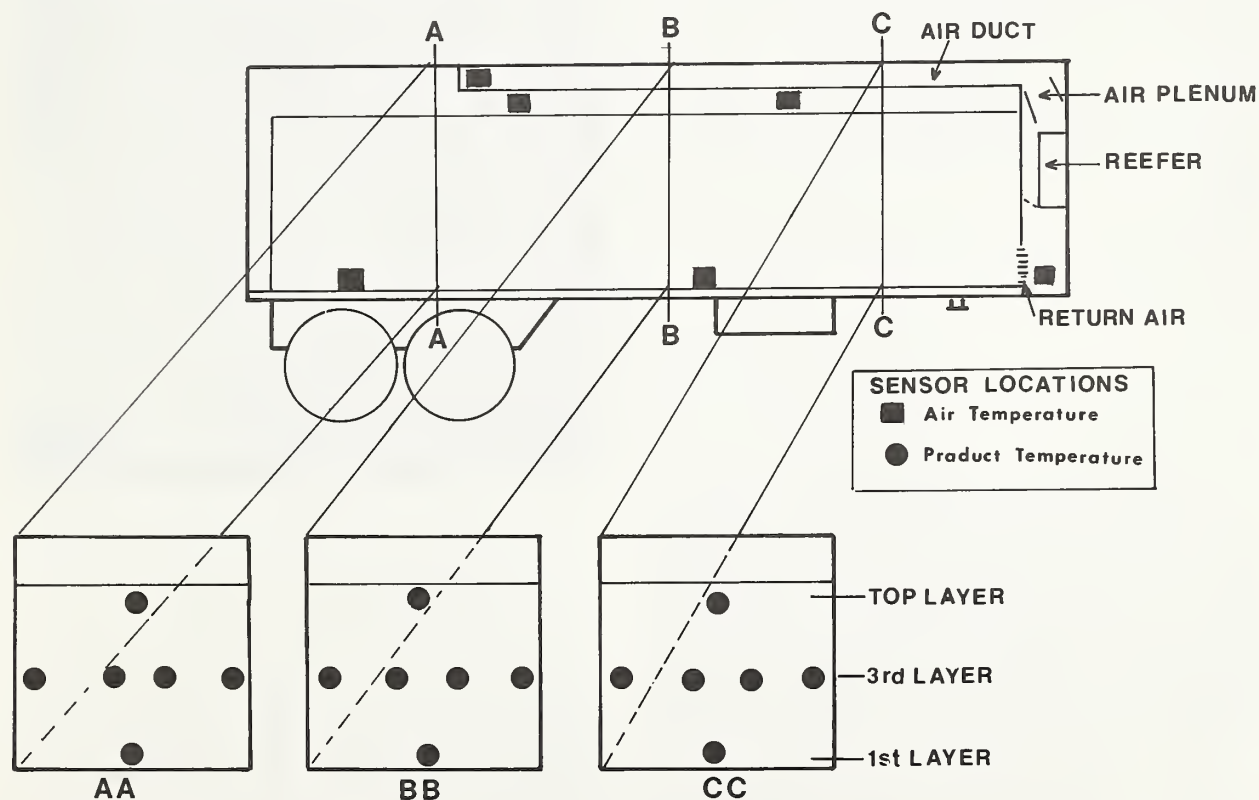
EQUIPMENT AND METHODS

In cooperation with manufacturers, an experimental van container⁶ designed by USDA researchers was tested in two ocean shipments from Florida to Europe. In the first test the USDA van was loaded with leatherleaf fern, and in the second test the performance of this van was compared with a conventional van used by a

commercial carrier when both were loaded with celery.

The principal difference between the two vans is in the method of air circulation. In the USDA van, refrigerated air (discharge air) passes through enclosed ducts at the ceiling, down sidewall flues, through the floor channels (which run crosswise), up through the load, and back to the air return at the top of the front bulkhead (Breakiron 1977). In the commercial van, the discharge air moves through a canvas duct from the front, above the load to a point three-fourths the length of the van, down the rear and sides of the load, through the load to the floor channels (which run lengthwise), and back to the air return at the bottom of the front bulkhead. The USDA van has squirrel-cage fans and a pressurized air circulation and distribution system. Its net cooling-capacity (Btu per hour) rating with air at 100° F (37.8° C) passing through the condenser is 15,000 at 0° F (-17.8° C) and 30,000 at 35° F (1.7° C). The commercial van has propeller fans and a nonpressurized air circulation and distribution system. The net cooling-capacity (Btu per hour)

⁶Van containers are hereafter referred to as vans.



END VIEWS OF SENSOR LOCATIONS THROUGH LOAD

FIGURE 1.—Locations of thermistor temperature sensors used to monitor product and air temperatures in commercial van.



FIGURE 2.—Rear view of USDA van, showing shipping boxes of leatherleaf fern on arrival in the Netherlands. Note the relatively tight stacking of boxes.

rating with air at 100° F (37.8° C) passing through the condenser is 15,500 at 0° F (-17.8° C) and 28,000 at 35° F (1.7° C). In the USDA van, the inside sidewalls are flat, and in the commercial van they are corrugated to facilitate air circulation.

Product and air temperatures were monitored at selected locations throughout each van (fig. 1). Thermistor sensors attached to a battery-powered magnetic tape recorder were used to record temperatures hourly from the time of loading until unloading. Each of 18 sensors was inserted into a bunch of fern or a stalk of celery in the center of a shipping box to obtain product temperatures in each van. A total of six air temperatures were recorded in each van. In the USDA van, discharge-air temperature was obtained at the floor of the van and return-air temperature at the top (opposite of that shown in fig. 1).

Relatively tightly stacked loading patterns were used in the USDA van for fern (fig. 2) and celery (fig. 3). In the commercial van, an air-stack pattern was used for the celery (fig. 4). The USDA van was loaded with fern on January 12, 1978, at Pierson, Fla., and trucked to Jacksonville. The ship left Jacksonville on January 16 and arrived in Rotterdam, the Netherlands, on January 26. The van was trucked to Aalsmeer and unloaded on January 28. The thermostat on the refrigeration unit of the van was set at 37° F. The USDA and commercial vans were loaded with celery on March 20, 1978, in Belle Glade, Fla., and trucked



FIGURE 3.—Rear view of USDA van, showing shipping boxes of celery on arrival in England. Note the relatively tight stacking of boxes.



FIGURE 4.—Rear view of commercial van, showing shipping boxes of celery on arrival in England. Note the air-stack loading pattern.

to Jacksonville. The ship left Jacksonville on March 22 and arrived in Felixstowe, England, on April 4. The vans were trucked to Horsmonden and unloaded on April 7. The refrigeration-unit thermostats on both vans were set at 34° F. Visual inspections were made of the loading patterns, shipping boxes, and the fern and celery on arrival at final destinations.

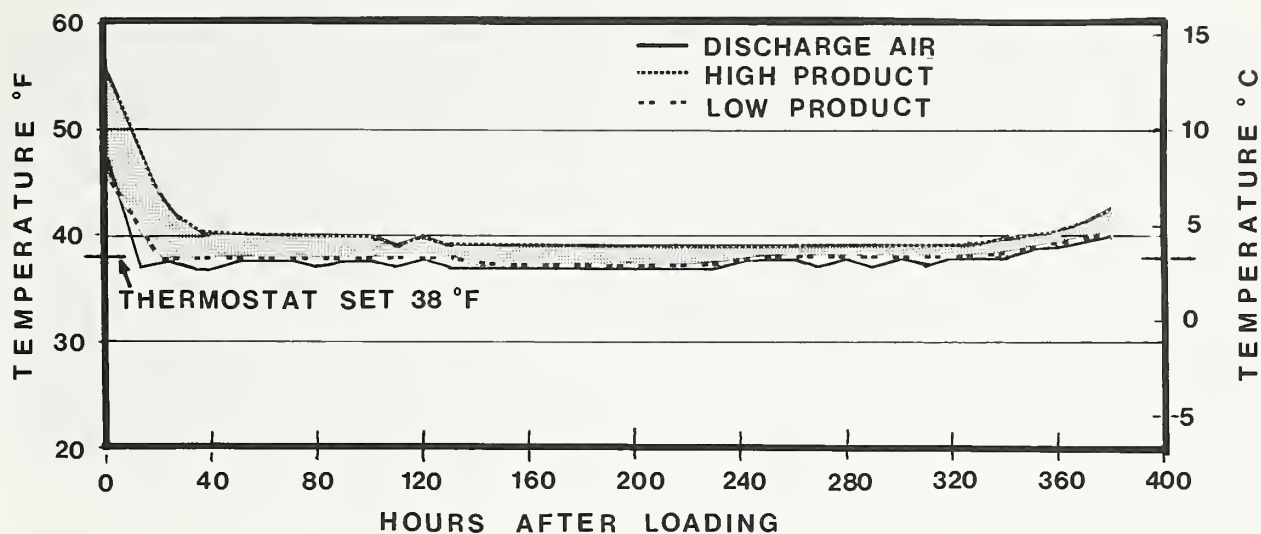


FIGURE 5.—Discharge-air temperatures and high and low fern temperatures in USDA van from Florida to the Netherlands.

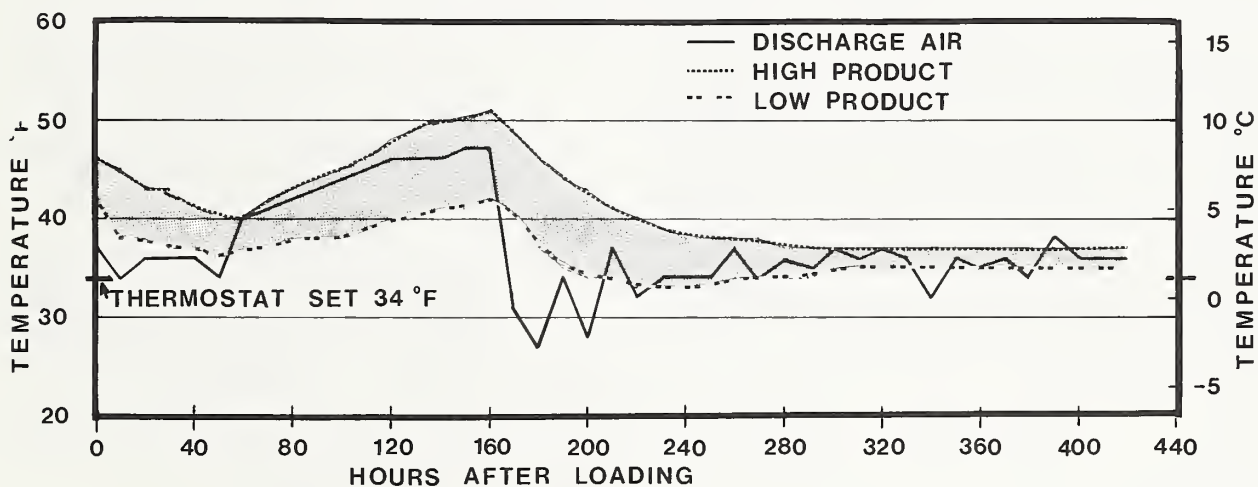


FIGURE 6.—Discharge-air temperatures and high and low celery temperatures in USDA van from Florida to England.

RESULTS

LEATHERLEAF FERN

The discharge-air temperatures and high and low product temperatures are shown in figure 5. At loading, product temperatures ranged from 47° to 55° F. Forty-eight hours after loading, product temperatures throughout the load ranged from 38° to 40° F and remained within that range until 135 hours after loading. They remained in the range of 37° to 39° F until 240 hours after loading. From 240 to 330 hours after loading (time of arrival in Rotterdam) the product temperatures

ranged from 38° to 39° F. At unloading, 375 hours after loading, the range was 40° to 41° F.

At unloading, the relatively tightly stacked loading pattern was intact, and there was no shipping-box damage (fig. 2). Examination of the fern in several shipping boxes throughout the load showed no heat or freeze damage. All fern had a fresh appearance, and no shattering of leaves was noticed.

CELERY

The discharge-air temperatures and high and low product temperatures for the USDA and

commercial vans are shown in figures 6 and 7. At loading, the product temperatures ranged from 41° to 46° F in the USDA van and from 42° to 48° F in the commercial van. After 48 hours in transit, the product temperatures ranged from 37° to 40° F in the USDA van and from 30° to 44° F in the commercial van. From that point the refrigeration units of both vans were inoperative until 160 hours in transit had elapsed, as can be seen by the temperature of the discharge air and increase in product temperatures. At the 160-hour point, the product temperatures ranged from 42° to 51° F in the USDA van and from 39° to 50° F in the commercial van. Both refrigeration units then operated properly until the end of transit, or 420 hours. On arrival, the average product temperature in the USDA van was 36° F, and temperatures ranged from 35° to 37° F. The average product temperature in the commercial van was 34° F, and temperatures ranged from 33° to 38° F.

On arrival, the loading patterns in the USDA and commercial vans were intact (figs. 3 and 4). In several shipping boxes throughout the loads in both vans, examination of the celery showed that bacterial soft rot had infected 5 to 25 percent of the stalks per box. There was no difference in the condition of celery in the vans. There was no evidence of freeze damage to the celery in either van, even though some product temperatures were as low as 30° F in one particular location in the commercial van.

DISCUSSION

The USDA experimental and commercial vans both performed satisfactorily in these tests. In the test with leatherleaf fern in the USDA van, the average product temperature was reduced from 49° to 39° F, with a range of 38° to 40° F, within 48 hours. In the test with celery in the USDA van, the average product temperature was reduced from 45° to 38° F, with a range of 37° to 40° F within 48 hours. In the commercial van, the average product temperature in this test was reduced from 46° to 37° F, with a range of 30° to

44° F, within 48 hours. Further, in the USDA van the range in product temperatures was narrower and closer to the thermostat setting after 48 hours in transit under conditions of relatively tightly stacked loads than it was in the commercial van with the air-stack loading pattern.

Advantages of the USDA van that were not measured in these tests are (1) more shipping boxes of product can be loaded if they are tightly stacked, thus utilizing available cubic space; (2) arranging of tightly stacked loads is easier than those that are air-stacked; and (3) tightly stacked loads allow column or register stacking of shipping boxes and thus use the strength of the boxes to advantage.

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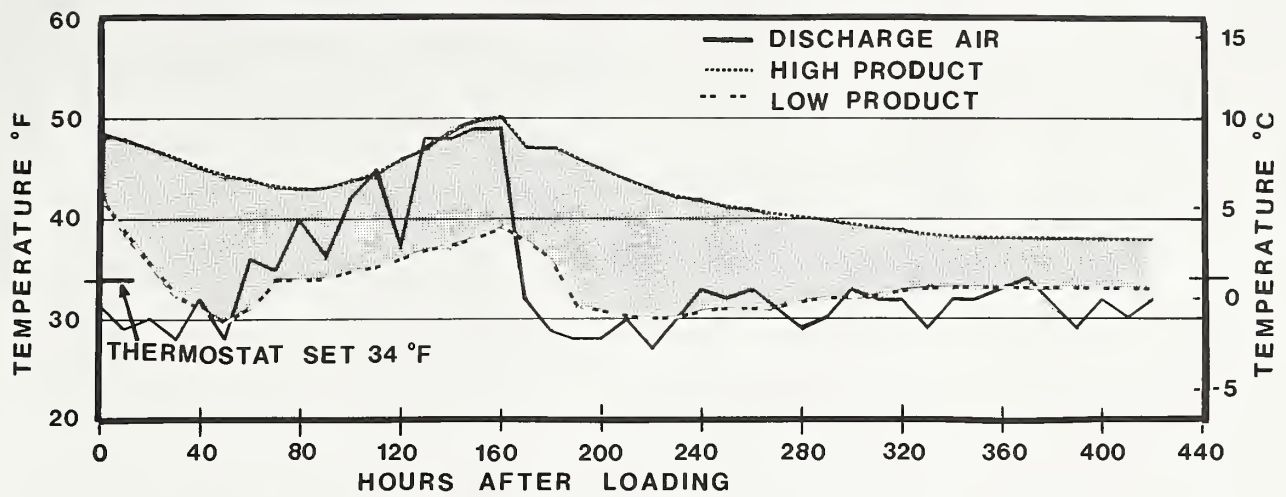


FIGURE 7.—Discharge-air temperatures and high and low celery temperatures in commercial van from Florida to England.

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